



# High-Temperature Systems for Oilfield Measurement-While-Drilling

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Workshop for Extreme Environments  
Technologies for Space Exploration

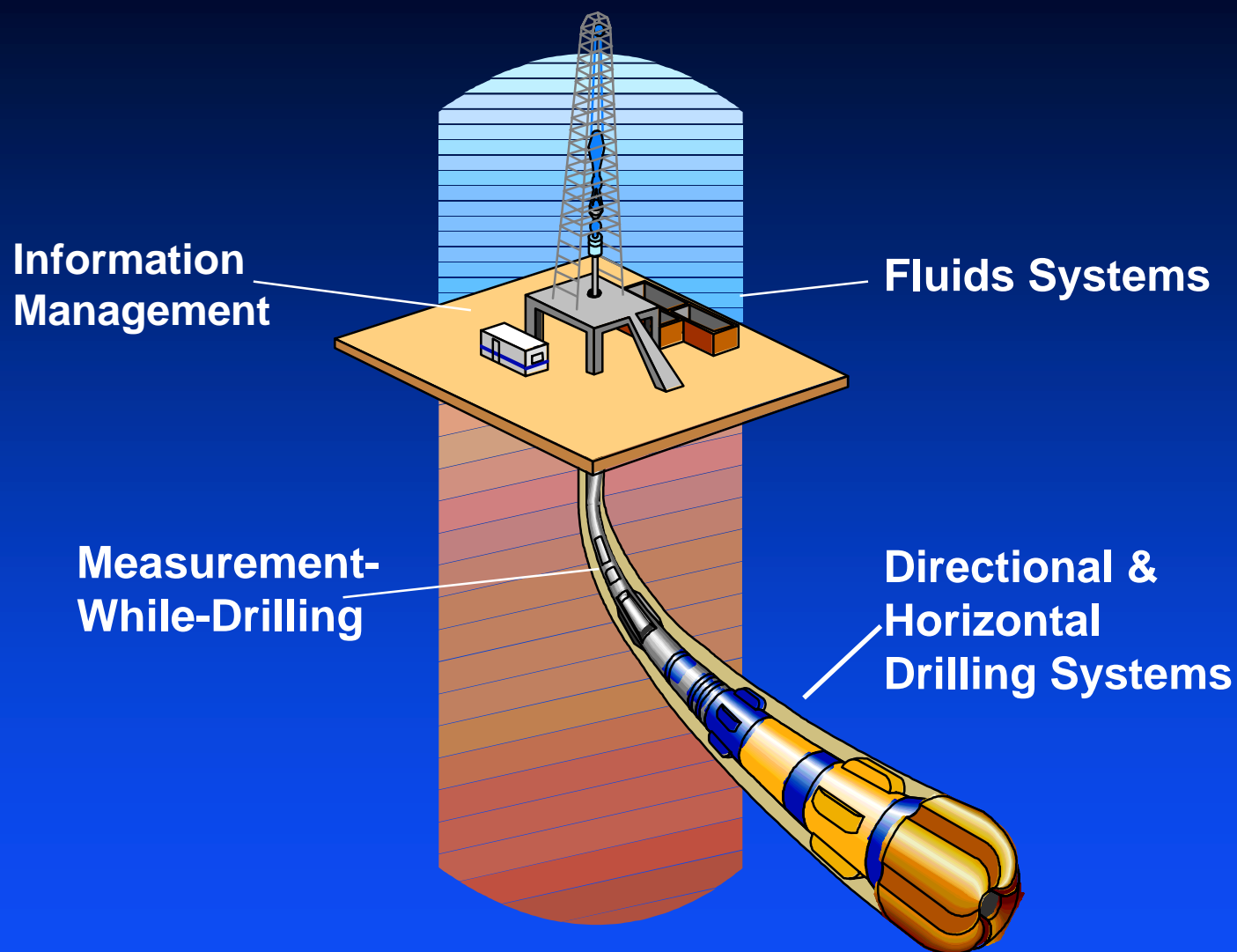
May 14-16, 2003

Pasadena Sheraton Hotel

NASA's Jet Propulsion Laboratory



# Drilling Systems





# MWD System



An MWD system operates remotely and autonomously in a hostile environment

- Measures Physical Parameters
- Processes Data
- Telemeters Data
- Records Data
- Makes Decisions

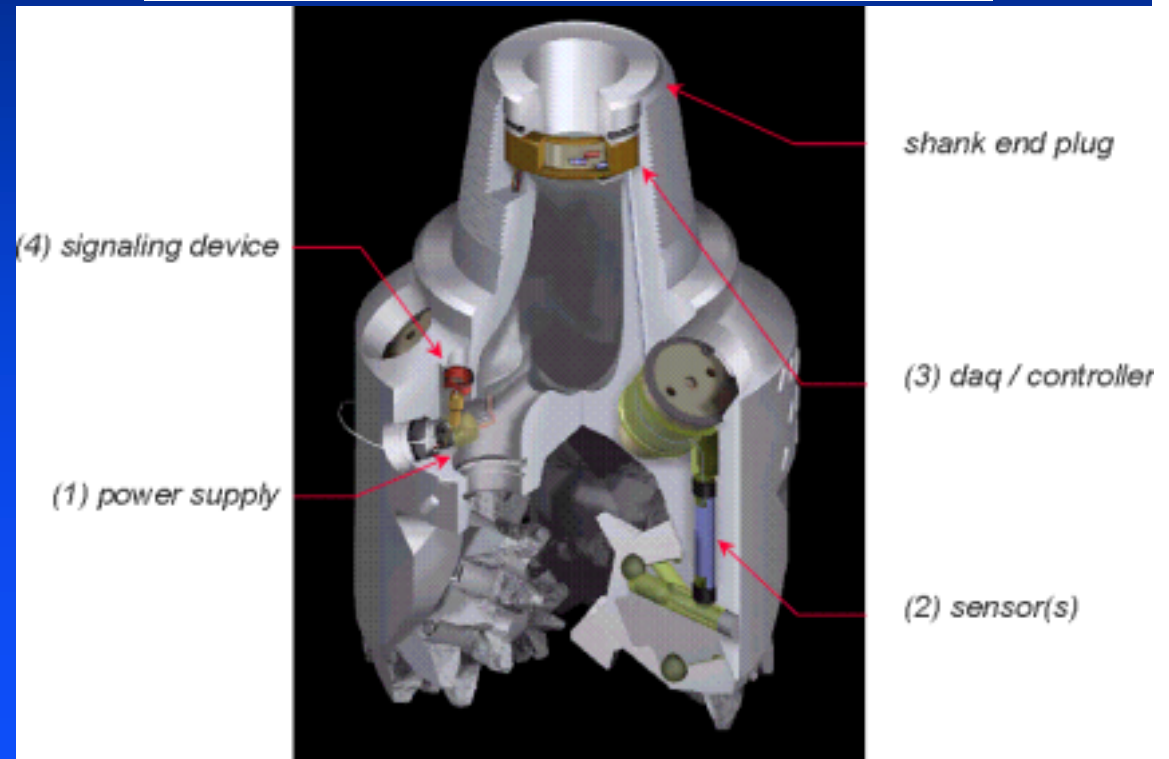
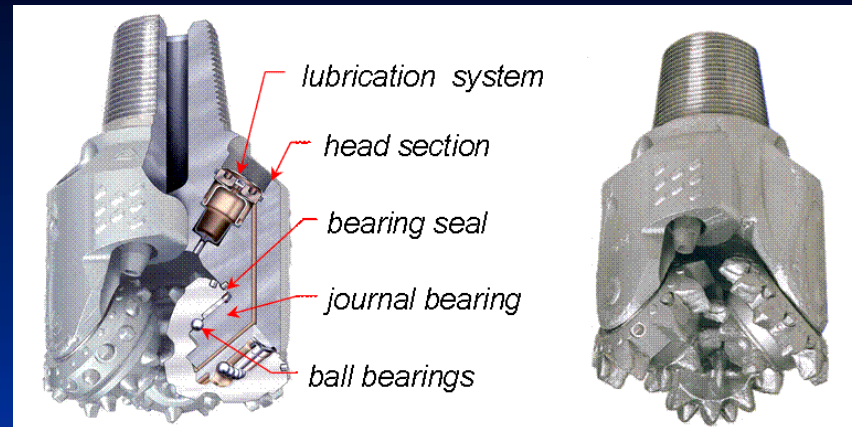


# Smart Bits for Drilling



- Monitor condition of lubricant, bit wear, drilling dynamics (VSS)
- Limited volume (~15 cc)
- High shock & vibration
- High temp & pressure
- Needs battery power
- Memory-only device stores computed results
- Expendable assembly

Upper limit  
presently is  
150°C





# Instrumented Coring Tools



- Retrieve sample of rock
- Directional alignment via magnetometer / accels
- Drilling efficiency
- Core integrity
- Preserve pressure

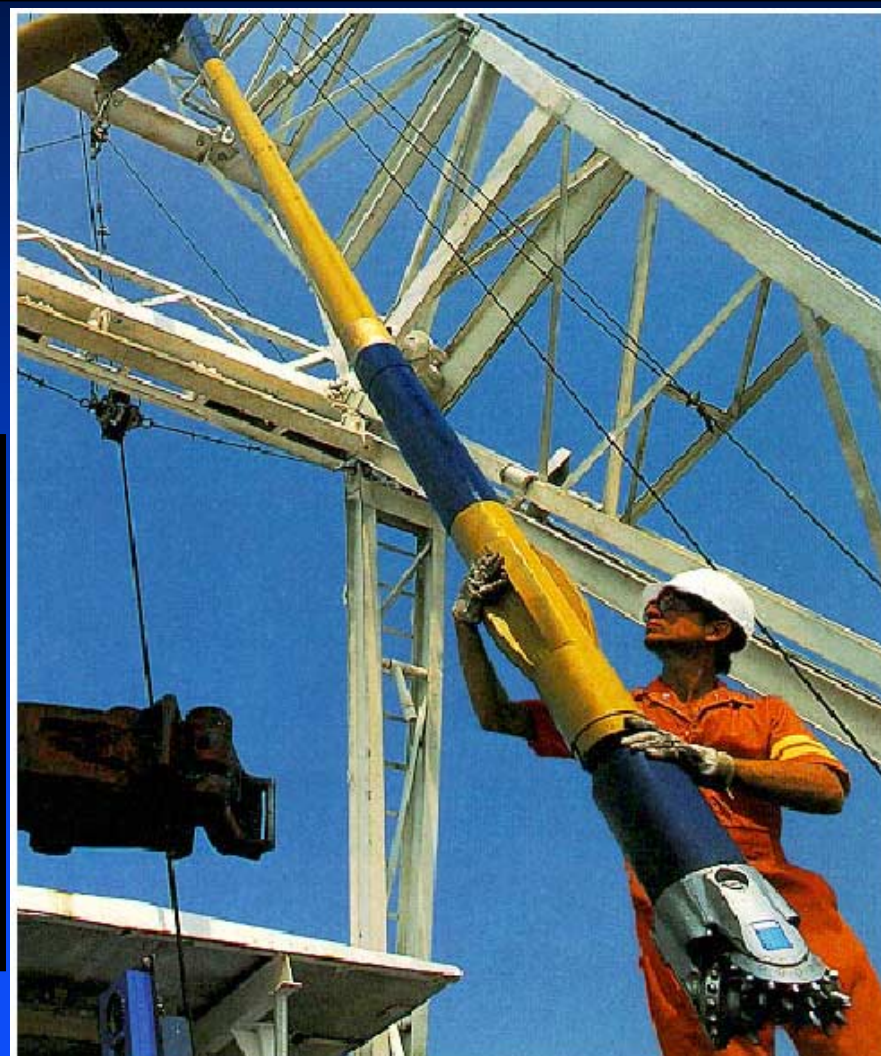
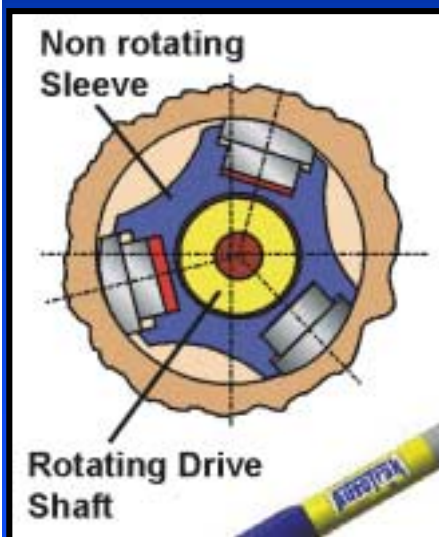
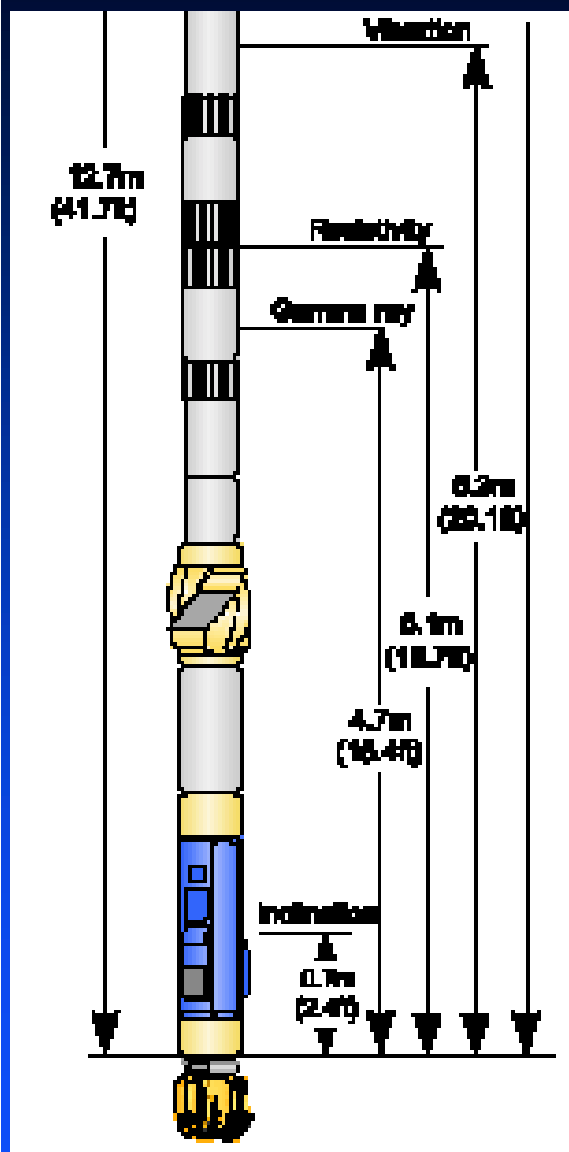




# Steerable Drilling Systems



Embedded electronics to 150°C

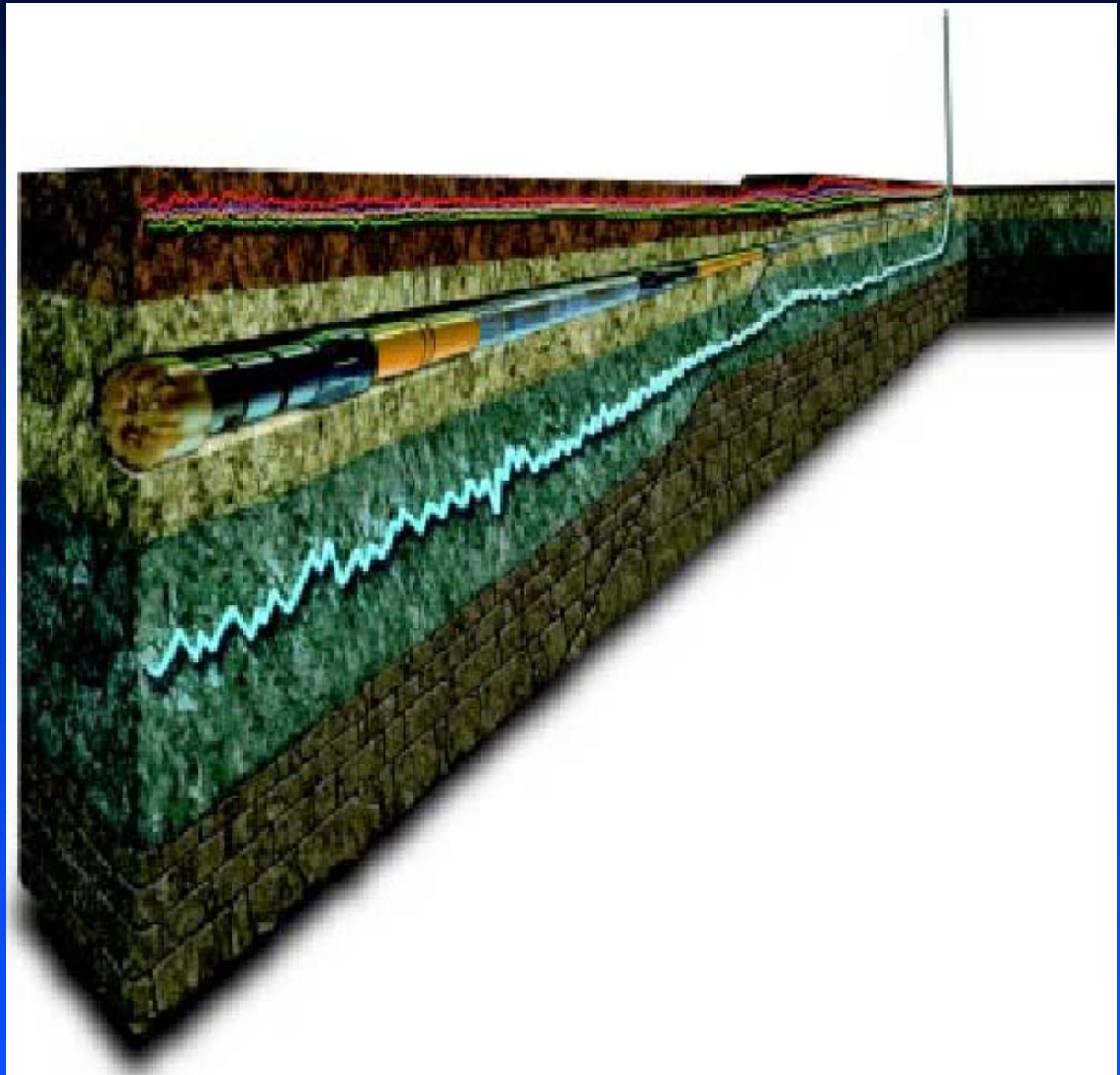




# Reservoir Navigation with MWD



- Geological steering within the reservoir rock at optimal level
- Formation evaluation in real-time
- Long, smooth horizontal sections
- Maximized oil and gas production





# Multilateral and Re-entry Wells





# High-Temperature MWD

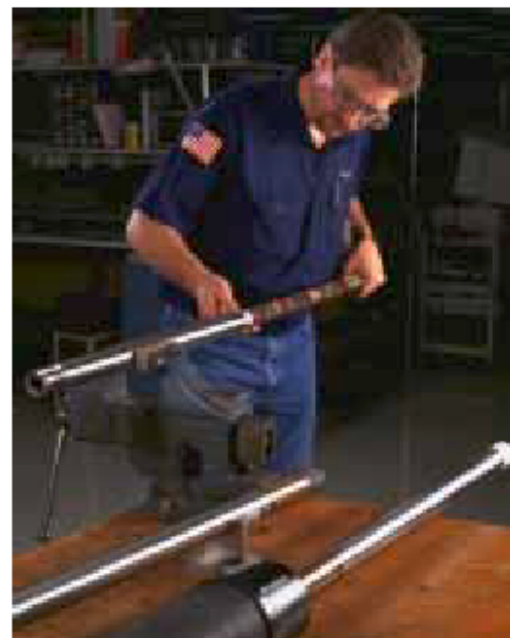


## High-Temperature MWD System

### Turning up the heat on high temperature MWD systems

Navi 185<sup>SM</sup>, Baker Hughes INTEQ's new high-temperature MWD system delivers reliable performance at an extended temperature range. This probe-style tool is engineered to provide real-time directional or directional/gamma ray measurements at temperatures up to 365° F (185° C). Additional sensors include tool temperature and vibration/stick slip measurement. Formation correlation is made possible by a gamma ray module which uses a dual stack of Geiger Mueller tubes positioned at the lower end of the tool.

The Navi 185 MWD system is available in multiple collar sizes including 4-3/4" and 6-3/4" tools. For more information regarding the high-temperature Navi 185 system, please contact your local Baker Hughes INTEQ representative today.



*The tool is powered by a Universal Power Unit turbine/alternator which can be configured for the particular tool size required. Specialized electronics ensure reliable operation at high BHTs.*

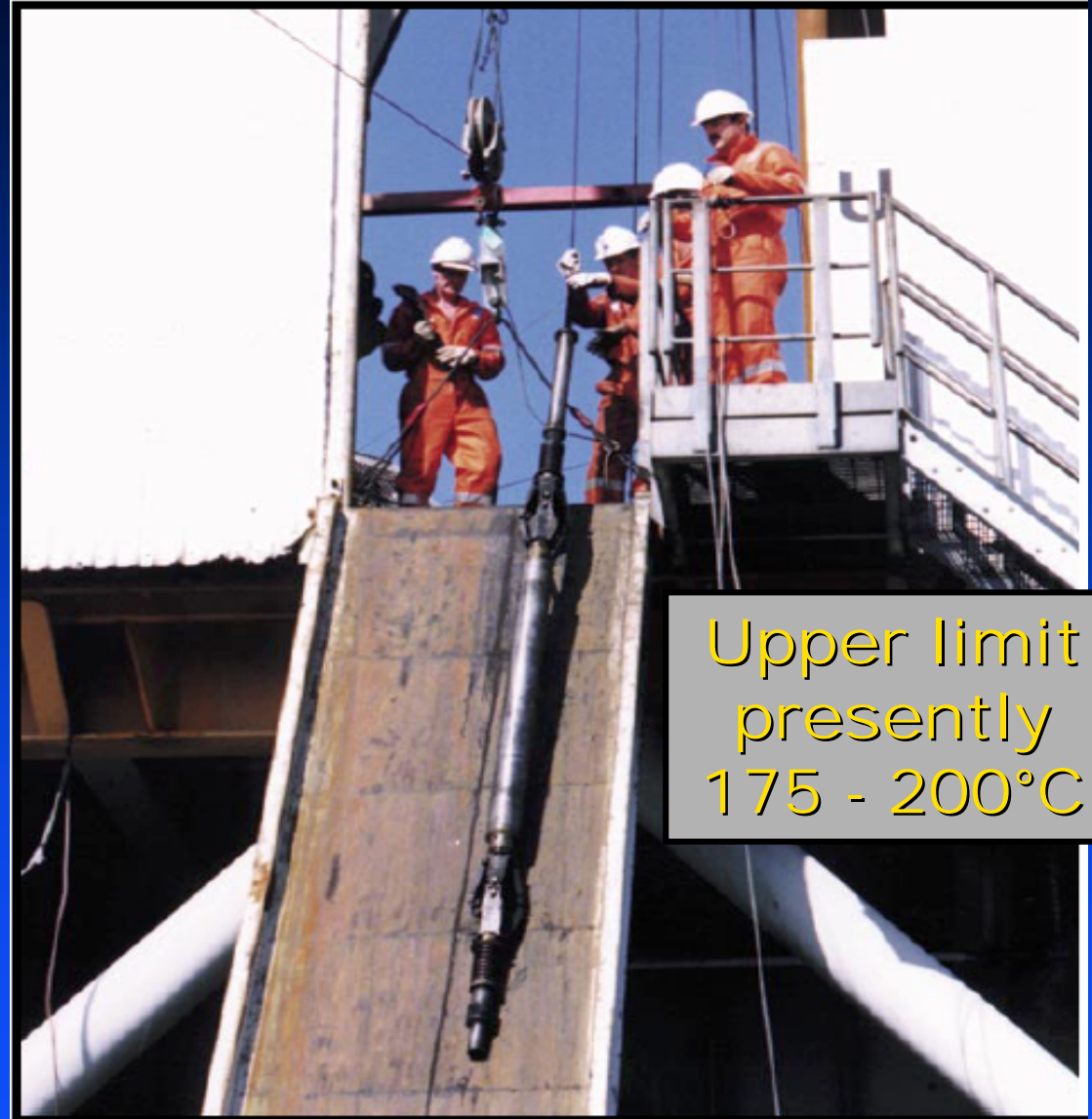
Upper limit  
presently  
is 185°C



# Wireline Well Logging



- Logging tool is attached to armored cable during run
- Communications and power via wireline
- Short duration in well; low vibration & shock
  - Directional survey of well trajectory
  - Formation evaluation prior to casing well
  - Logging well after casing is in place



Upper limit  
presently  
175 - 200°C

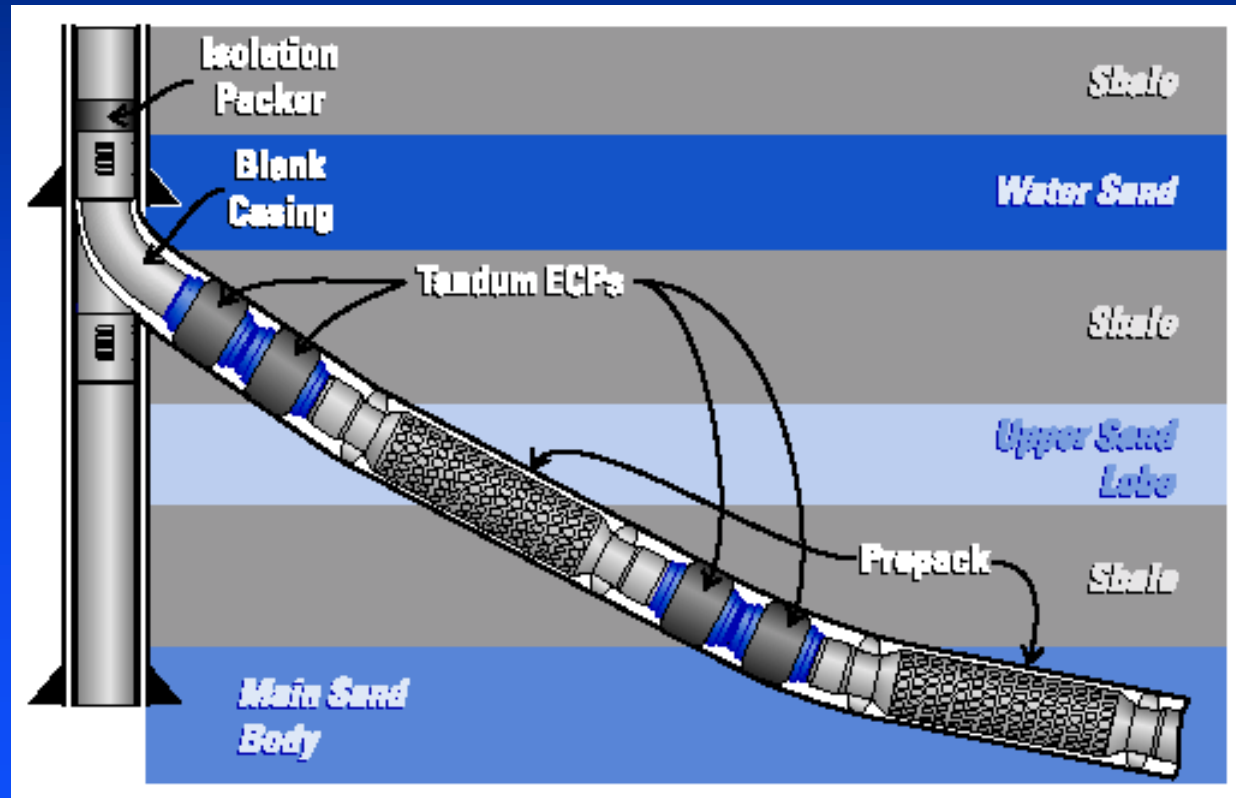
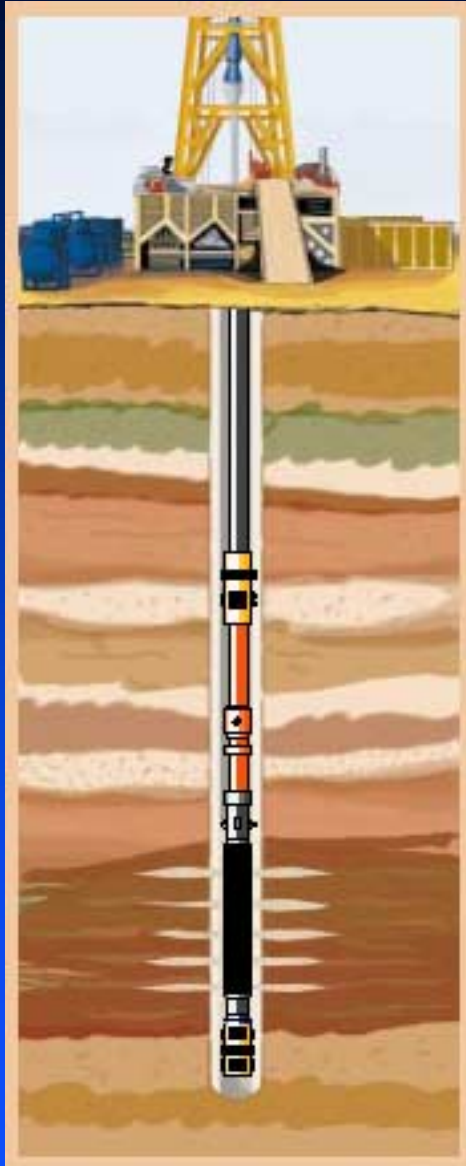


# Completion and Production



- Intelligent well completions
- Sub-surface safety valves
- Long-term production monitoring

Long-term  
reliability  
unproven





# Downhole Applications



## Future application needs driven by deep water developments

Mission Type	BHI Division	Mission Time (hrs)	Low Temp (C)	High Temp (C)	Pressure (bar)	Other Environmental Conditions
Smart Drill Bits	Hughes Christensen	24 - 200	-40	250	2000	Shock, vibration, erosion, abrasion
Measurement While Drilling	INTEQ	12 - 200	-40	225	2000	Shock, vibration, erosion, corrosion
Wireline Logging	Baker Atlas	3 - 10	-40	250	2000	Corrosion
Intelligent Completions	Baker Oil Tools	4 - 20	-40	250	2000	Shape charge percussion
Production Monitoring	Baker Oil Tools	5 – 15 years	0	250	1333	Corrosion
Instrumented Pumps	Centrilift	2 – 10 years	0	200	1333	Corrosion



# Materials Issues for MWD



- Steel is a load-bearing portion of drilling assembly
  - Strength, elasticity, fatigue, geometry limitations
  - Non-magnetic properties required in many portions
  - Corrosion: Cl<sup>-</sup> Stress Cracking, H<sub>2</sub>S, embrittlement, over-aging (BeCu)
  - Deep water (>5000 ft) making increased demands (30,000 psi)
  - No capability to use large dewar flask
- PCB – polyimide available is hygroscopic (bake before assembly)
- Elastomers
  - Running in abrasive materials (mud, rock walls)
  - Gas permeability tends to delaminate & swell (CVD metallization tried)
  - Vibration dampening / suspensions deteriorate at high temp
- Antennas need protection from rock wall abrasion, impacts
- Chemistry is accelerated (batteries, coating interactions)



# Methods for Achieving High-Temp

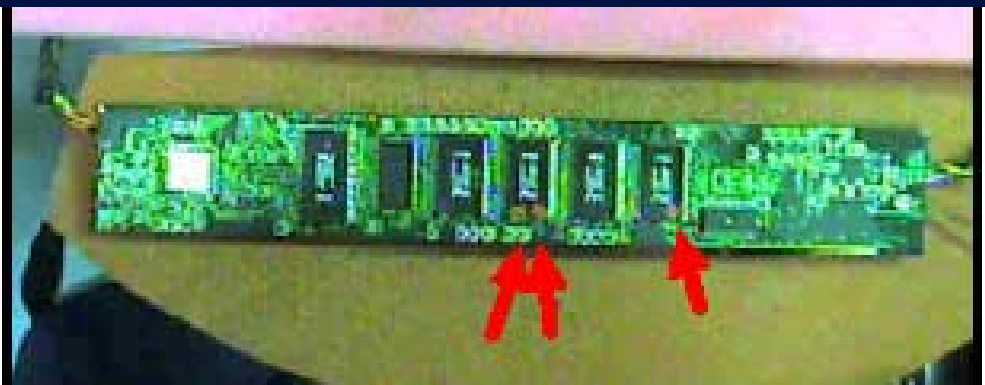


- COTS (Commercial Off-The-Shelf)
  - Pre-screened by vendor
  - Buy and test in-house
  - Contract out for screening and / or upgrades
  - Buy lifetime supply of proven mask / lot
- Qualified parts rated for high-temperature
  - Hard to find
  - Fewer Mil-spec parts being made, but we use when possible
  - High-reliability versions not available for new designs
- Heat management schemes
- Compromises and trade-offs in HW / SW system tasks
- Joint Industry Projects for development of high-temp technology

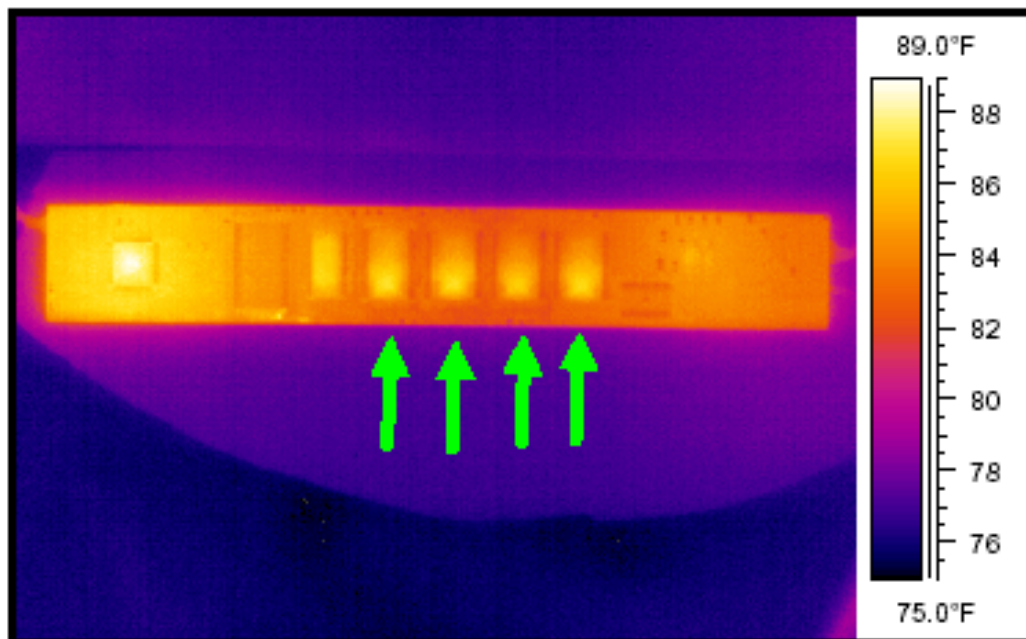
Making do  
with what is  
available



# Radiometric IR Imaging



Re-designing to  
minimize hot spots



## PCB Analysis: OnTrak Master/Memory

Bad Board Overview - Flash Side  
After Initialization  
1-4 Flash Chips Warm

IR information	Value
Date of creation	4/25/2003
Time of creation	8:40:32 AM
Camera type	S60 NTSC
Camera lens	24

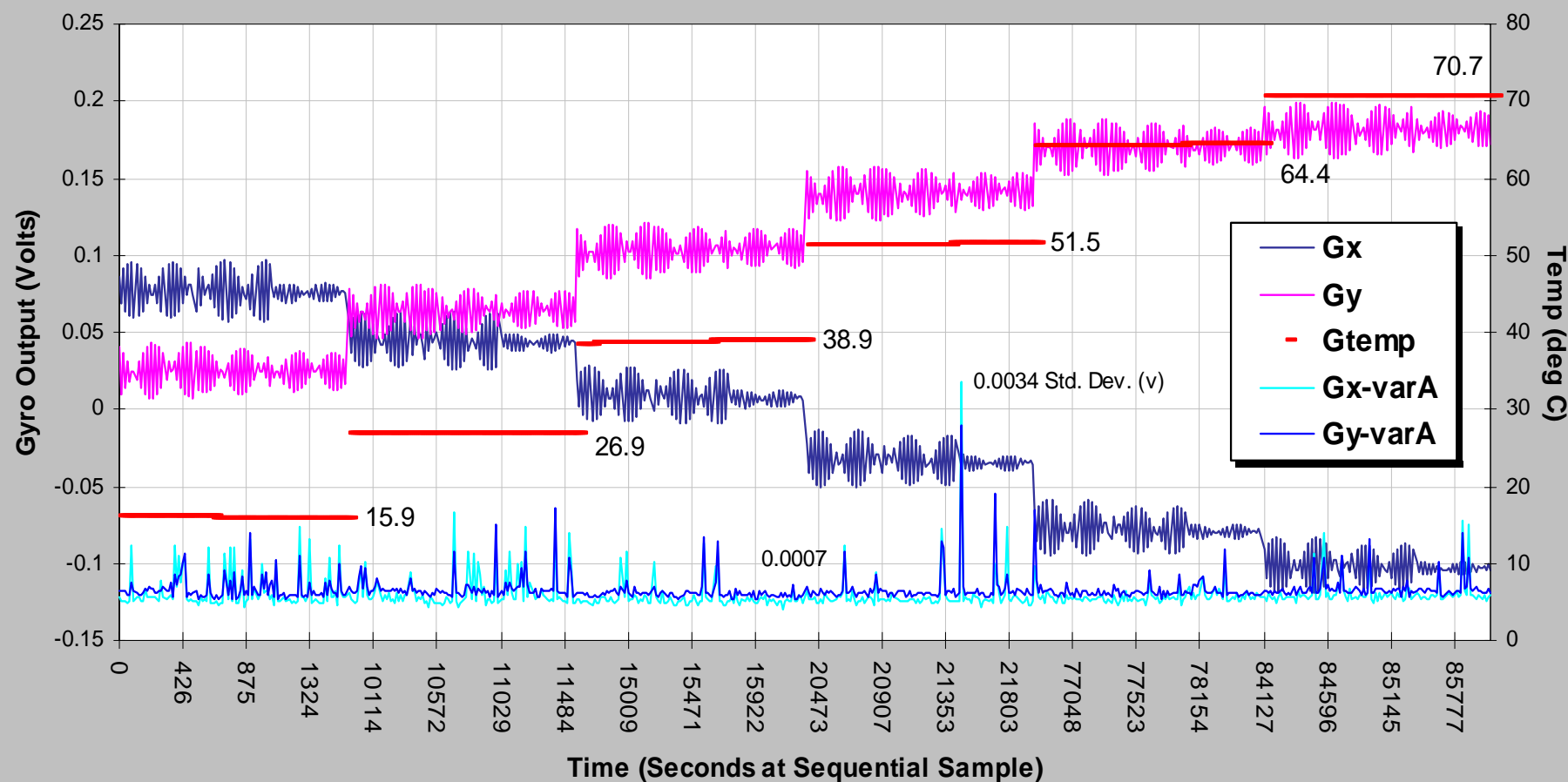




# Sensor Modeling vs. Temp



## MWD Gyro Thermal Calibration Gyro #1682 9/9/98



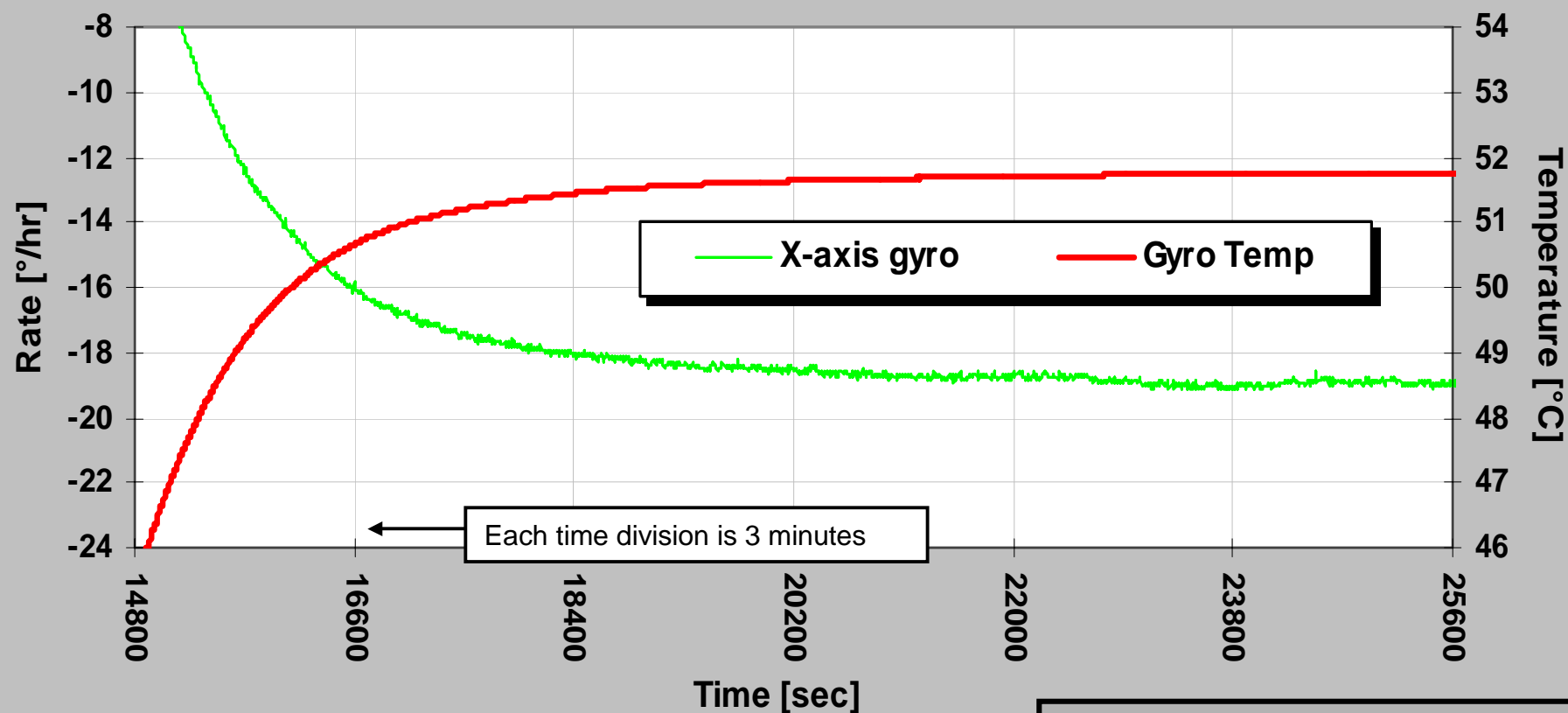
Modeling to extend usable sensor range



# Sensor Turn-on Thermal Stabilization



## Gyro Turn-On Test - Sensor 1682, 02-Sep-1998



Compromising for  
accuracy / power



# Reliability Aspects of GyroTrak®



- Designed in BEST of current sensors and mechanisms
  - Picked rugged military tactical gyro used in F-22 & BAT
  - Using stepper motor with well-established reliability
  - Using new, smaller Mini-Q-Flex accelerometers
- Selected high-temp qualified parts (motor rated 200°C)
  - Electronics designed for excess capacity, speed, inputs
- Chose PCB mounting method lab-proven best for 150°C
  - Ran Finite Element Analysis to pinpoint amplification areas
- Tested and verified robust performance in vibe & shock
  - Critical parts tested well beyond 20 g rms vibration spec
  - Stability of accuracy verified in calibrated test stand
- Implemented new O-Ring mount shock dampening techniques

Designing  
with best  
practices  
approach



# Torsional Shock Tester



- Built to simulate downhole “stick-slip” conditions
  - Amplitudes based on downhole measured field data
  - Scaled to 50 times worst-case experience level



Designing  
beyond  
worst-case  
conditions

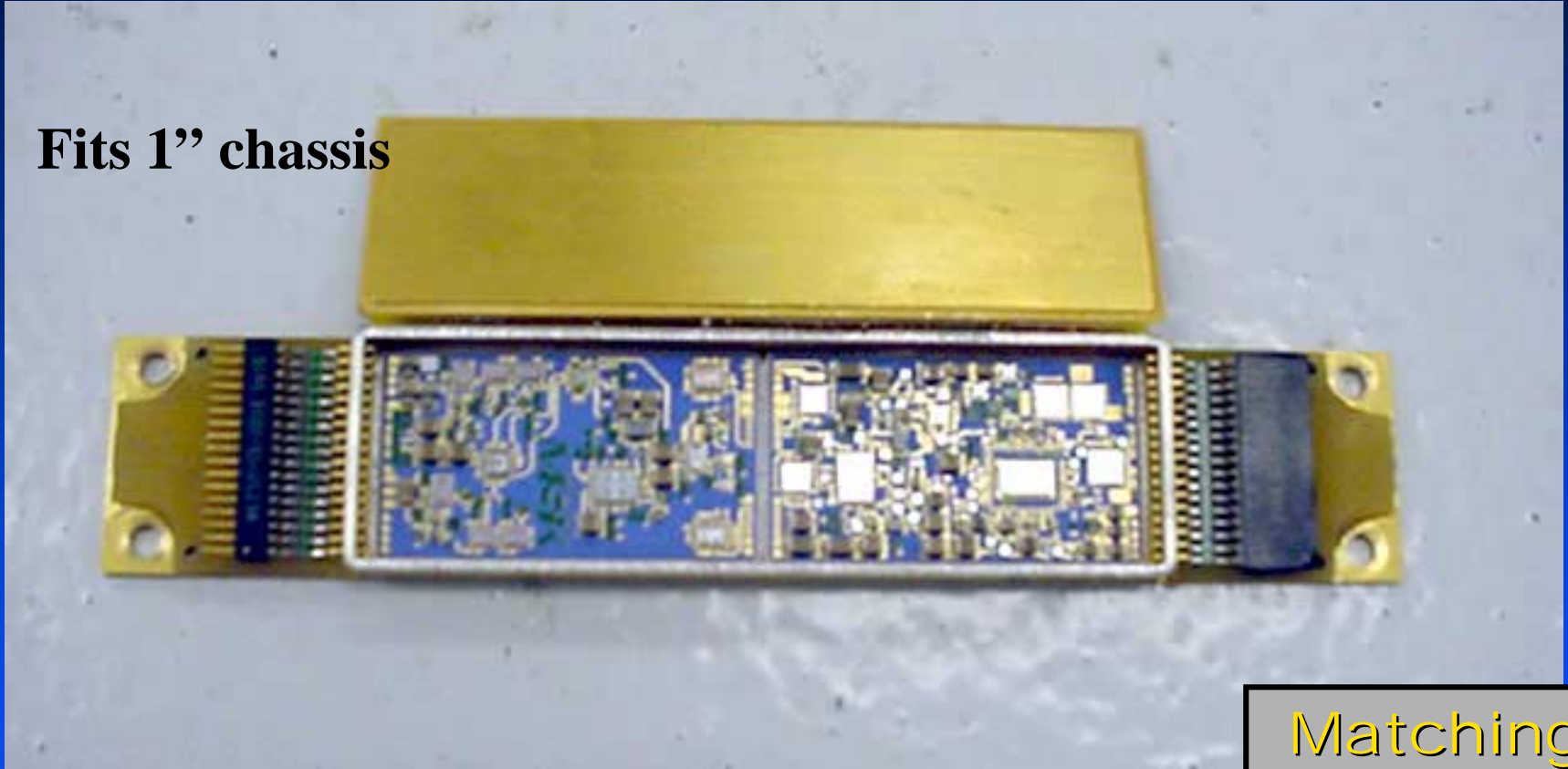


# Hybrid MCM for GyroTrak®



## Ceramic on Moly Substrate - Heatsink

Fits 1" chassis



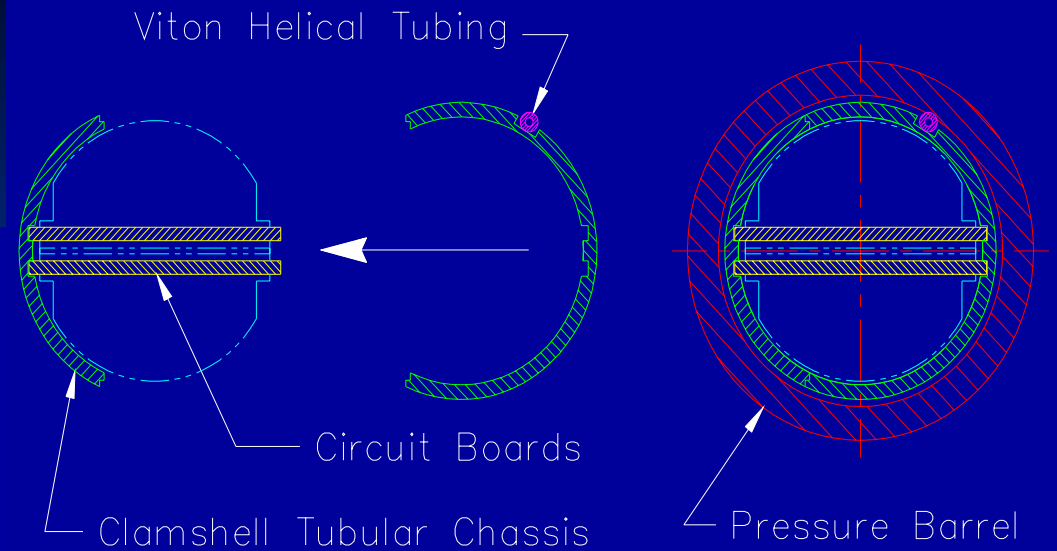
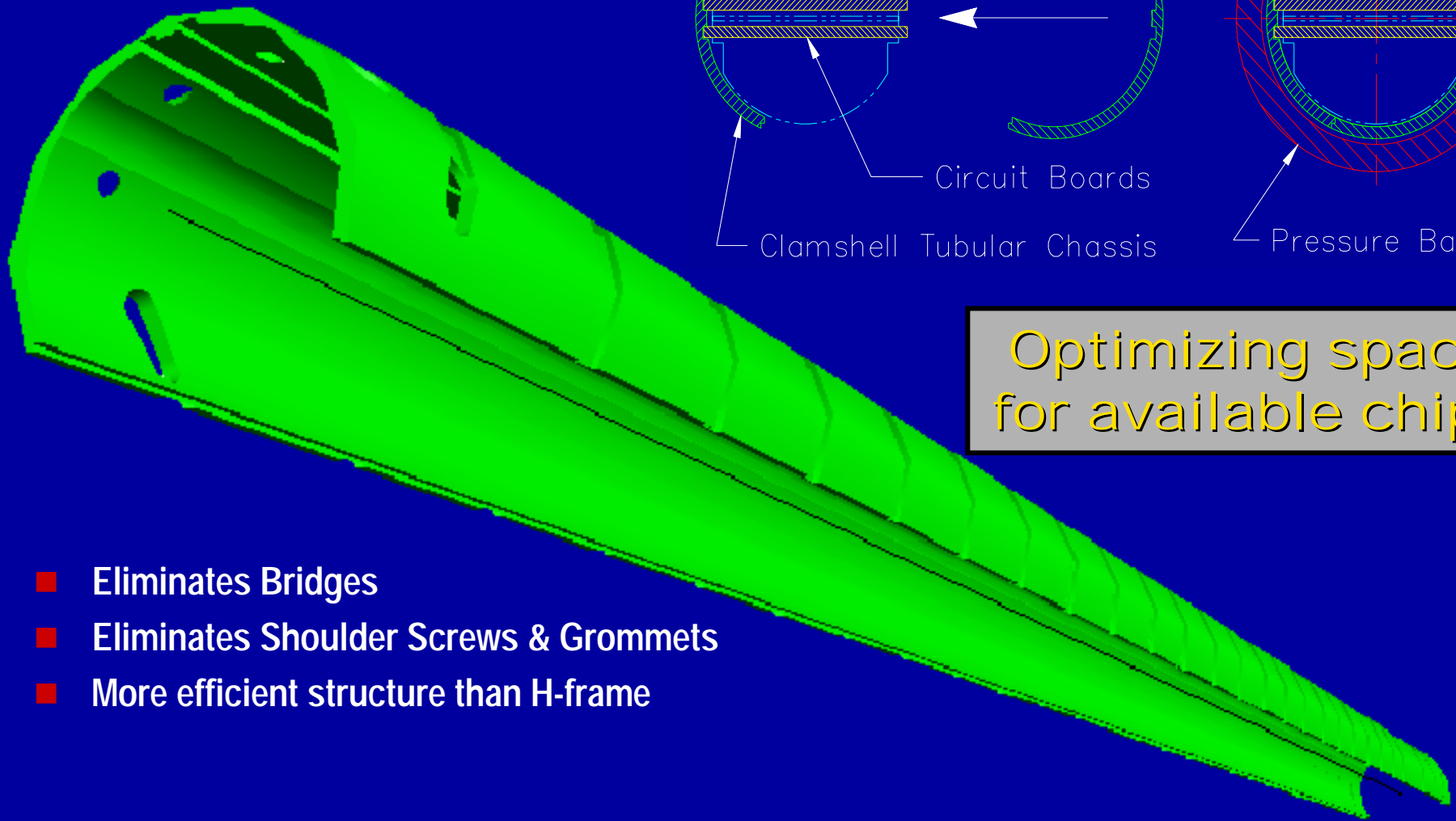
Matching  
TCE for  
reliability



# Clamshell Tubular PWA Chassis



## "Tube-Pack" Electronics Chassis



Optimizing space  
for available chips

- Eliminates Bridges
- Eliminates Shoulder Screws & Grommets
- More efficient structure than H-frame



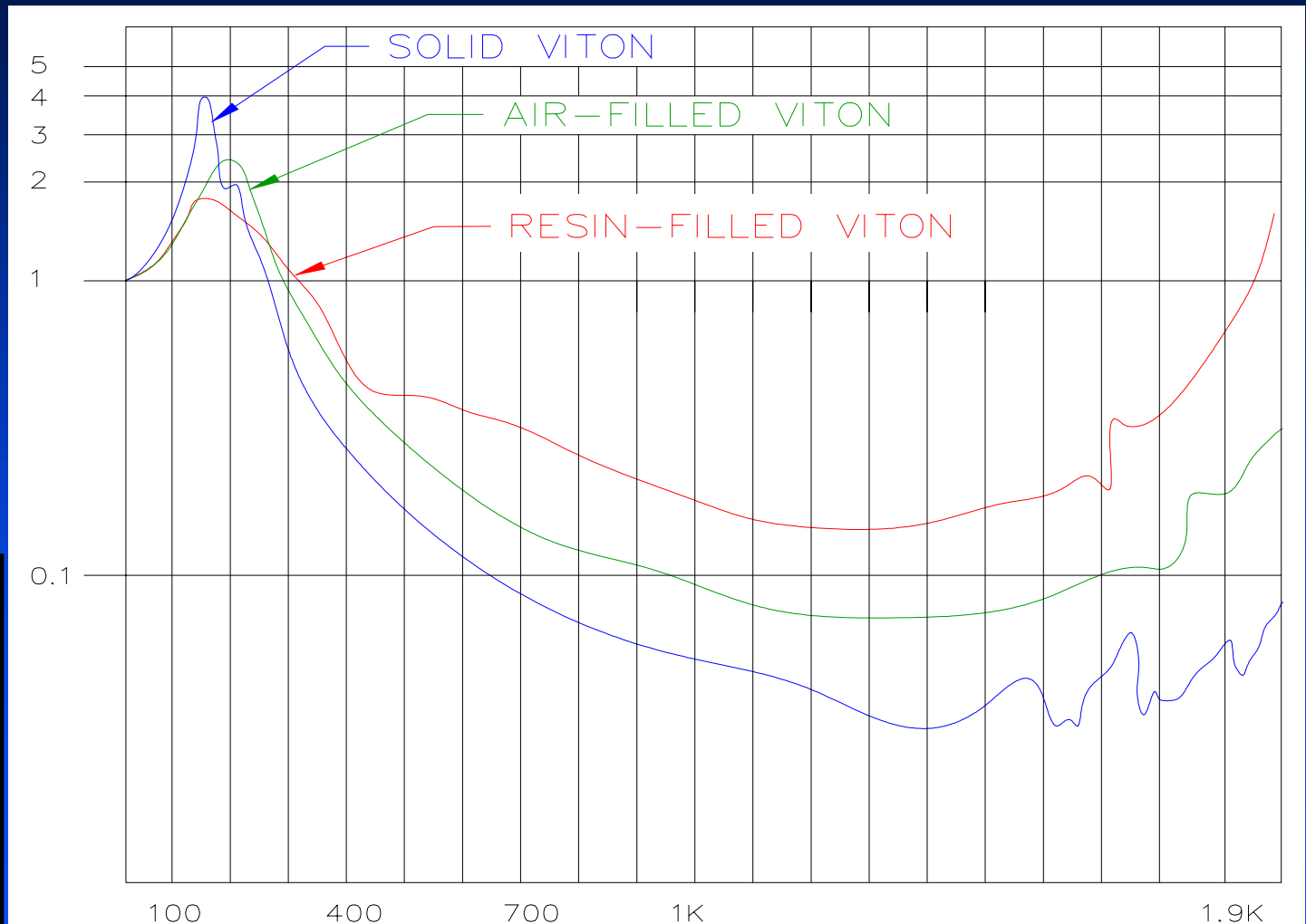
# Vibration Isolation



## O-ring Suspension Research Testing

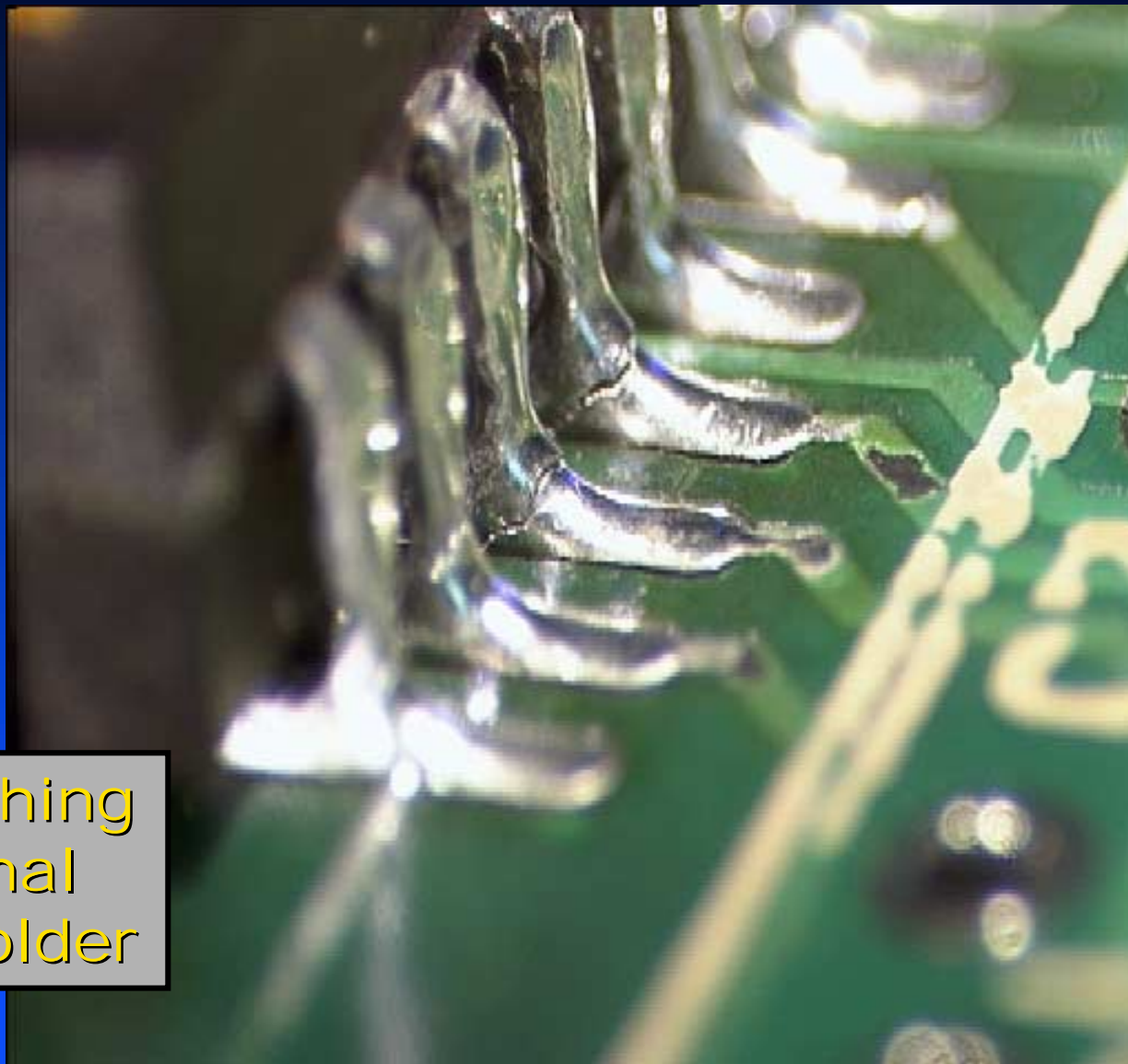
Amplification  
Factor  
“Q”

Testing  
iteratively  
to  
optimize  
design





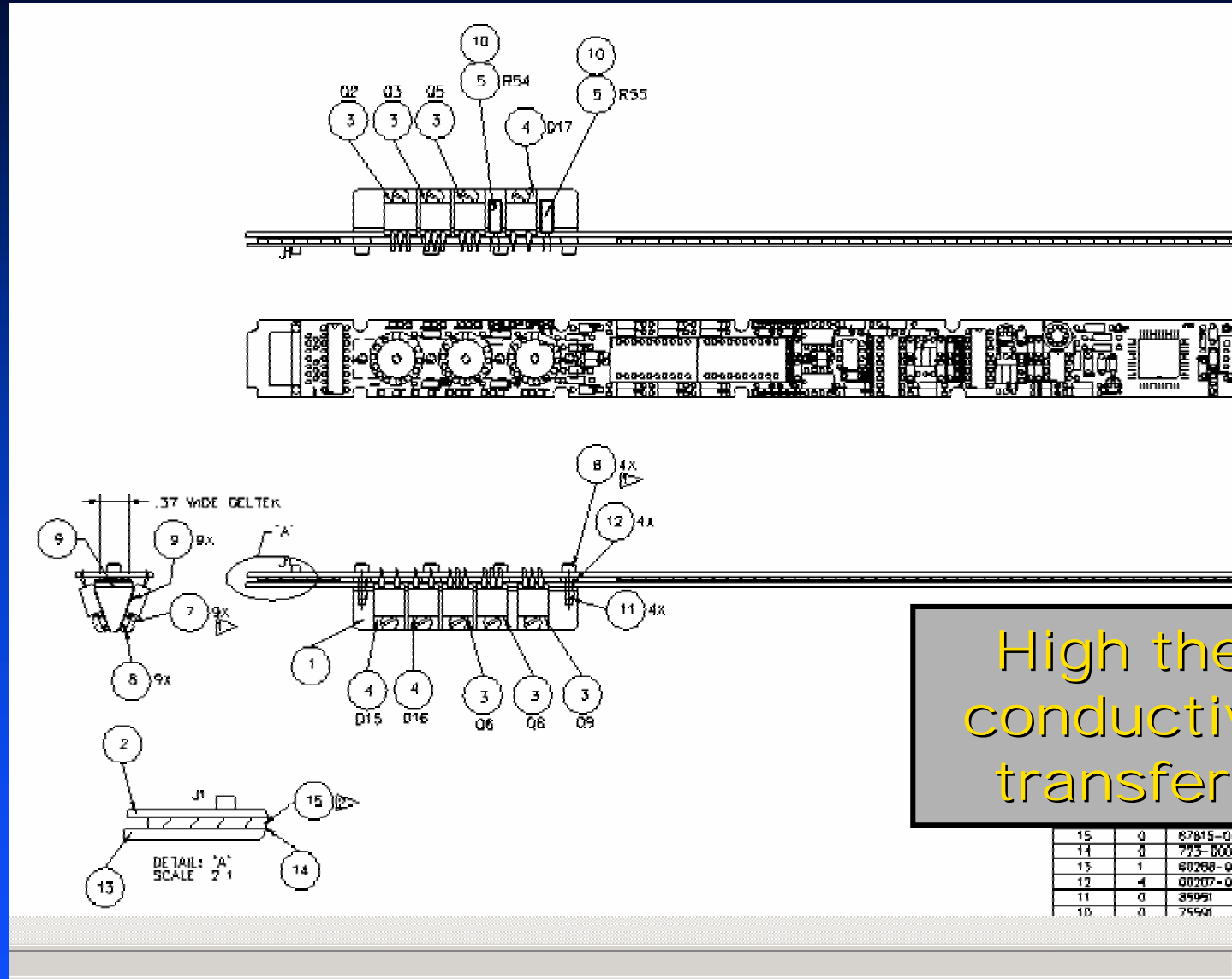
# Interconnection / Solder Problems



Still searching  
for optimal  
Hi-temp solder



# Thermal Dissipation Heat Strip





# FPGA Implementation

## High-Temp UART Required for DSP

Original layout with dedicated UART chip



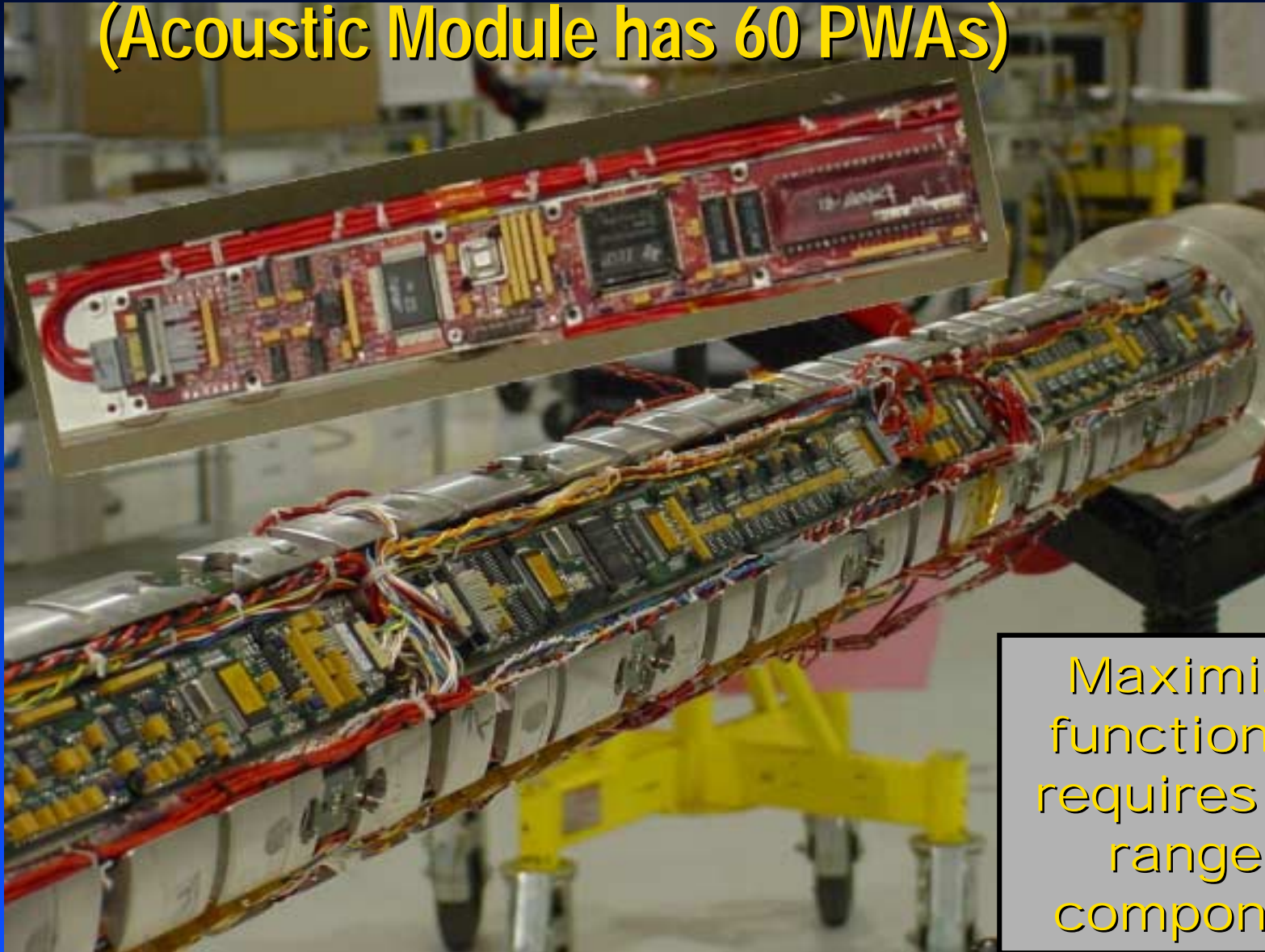
Revised layout with UART function in FPGA chip



Compromising  
with mix of  
Hi-temp parts



# Complexity of MWD Electronics (Acoustic Module has 60 PWAs)



Maximizing  
functionality  
requires wide  
range of  
components



# Joint Industry Proposal



## Honeywell High-Temp SOI HTMOS

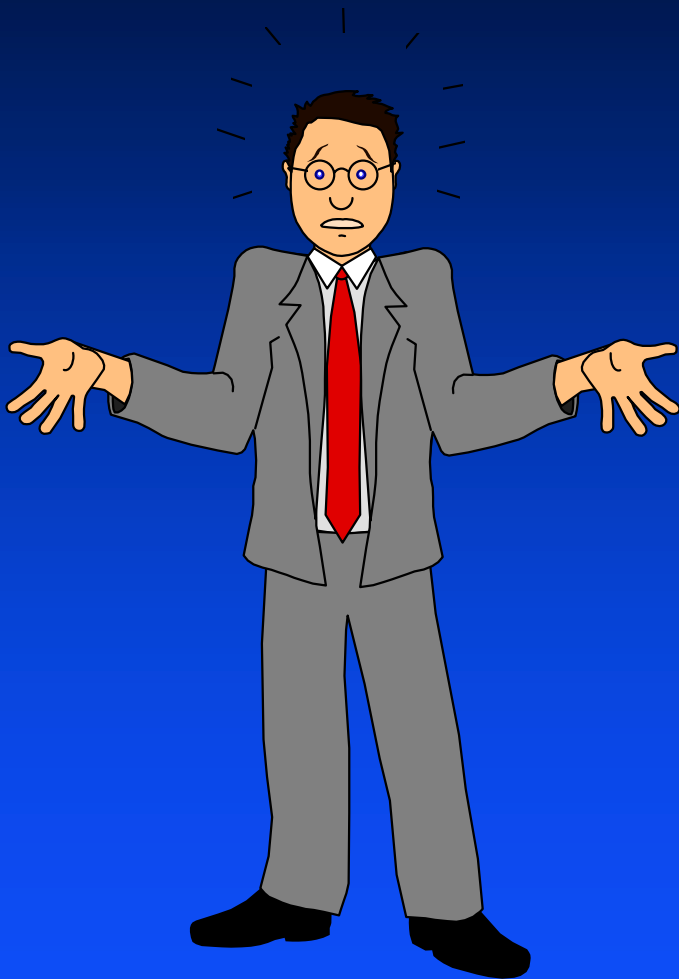
- Deep Trek JIP is mainly funded by the DOE
- Will deliver guaranteed 5-year life at 225C
- Limited product offering
  - Answers needs for minimal systems
  - Leaves big gaps for complex MWD and wireline systems
- Funding needed in lieu of a high-volume market
- A good start on a long road



# Oilfield High Temp Development



## A Funding Dilemma



- Major oil companies have been reducing internal R&D capacity
- Service companies have been expected to provide newer, better technology
- Industry recession is squeezing revenues
- Service company R&D budgets suffer
  - Technology efforts delayed or canceled
- Government and JIP funding can help
  - Choose projects critical for future
  - But all Hi-temp users together are still a tiny market -- **small potatoes !**
- Oil companies must help fund promising technology developments, or do without